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U.S. PATENT APPLICATION

For

Stereoscopic Display System

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TITLE OF THE INVENTION

Stereoscopic display system

FIELD OF THE INVENTION

[0001] The present invention relates to stereoscopic display systems. More specifically, the present invention is concerned with high quality flat panel stereoscopic display systems.

BACKGROUND OF THE INVENTION

[0002] Stereoscopic technology is used to create realistic games or scenery providing depth to objects, by presenting a unique view to each eye of a viewer almost the same way the viewer would view objects in real life. In polarization technology, linear polarized and circularly polarized lights as well as a combination thereof, referred to as elliptically polarized light, are used.

[0003] A conventional stereoscopic display system uses passive polarized stereoscopic glasses comprising two filters at 90° from each other and generates two images polarized at 90° from each other. Figure 1 illustrates such a system, where **L.I.** is a left image intended to be seem by the left eye only, **R.I.** is a right image intended to be seem by the left eye only, **L.F.** is a polarized left filter, which lets only the left image go through, and **R.F.** is a polarized right filter, which lets only the right image go through.

[0004] In liquid crystal display LCD) technology, three types of active matrix Thin Film Transistor (TFT) LCD are used: Twist Nematic (TN), In-Plane Switching (IPS) and Multi-domain Vertical Alignment (MVA). A LCD display consists essentially of two sheets of glass separated by a sealed-in liquid

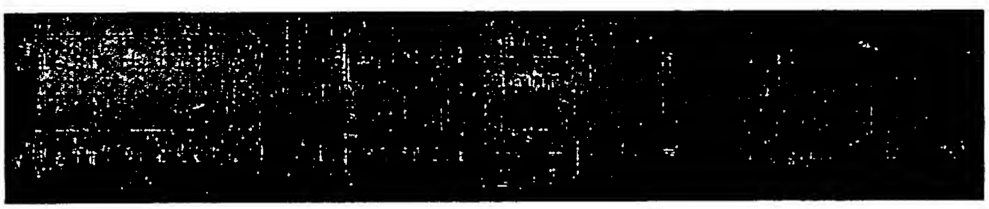
crystal material, which is normally transparent. A voltage applied between front and back electrode coatings disrupts an orderly arrangement of the liquid crystal molecules, darkening the liquid enough to form visible characters.

[0005] In a United-States patent No. 5,629,798 issued to the present applicant, a deep 3D perception is achieved by showing two images from a different point of view corresponding to each eye of the viewer, as in stereoscopy, with a unique advantage of displaying the two images without multiplexing them in time nor in space as is usually the case in most others stereoscopic technologies. The method consists in adjusting, for each picture element individually, the intensity of light as a function of the intensity value of two corresponding pixels in the left and right images, and polarizing, for each picture element individually, at an angle depending on the value of the two corresponding pixels of the left and right images. The resulting display is similar to any conventional LCD monitor but it comprises two LCD panels. The display comprises a series of layers, comprising, from back to front, a back light panel, a first polarized filter, a first LCD panel (Mod LCD), a second polarized filter and a second LCD panel (Ang LCD). The first LCD panel controls the pixel intensity for both eyes while the second LCD panel controls the distribution to one eye or the other. To generate a stereoscopic image, the left and right images are converted into a modulo (driving the first LCD) and an angular (driving the second LCD) images using the following relations:

$$\text{Modulo} = \sqrt{(\text{left}^2 + \text{right}^2)} \qquad (1)$$

$$\text{Angular} = \arctan\left(\frac{\text{left}}{\text{right}}\right) \qquad (2)$$

[0006] The orthogonal polarized filters of the passive glasses recreate the left and the right image for the left and the right eyes, since these polarized filters act as cosine and sine trigonometric functions as follows:



[0007] In spite of developments in the field, there is room for further improvements in the field of high quality flat panel stereoscopic displays.

SUMMARY OF THE INVENTION

[0008] In accordance with the present invention, there is provided a polarized display, comprising: an intensity modulating matrix display having a front surface; and a polarizing matrix display panel in front of said intensity modulating matrix display, the polarizing matrix display panel having a front surface; wherein the display is one of: a linear polarization display, each pixel of the polarizing matrix display panel being controllable and a rotation of a generated polarized light being varied over a range including 90 degrees and below; and: an elliptical polarization display, each pixel of the polarizing matrix display panel being controllable and a phase between a fast and a slow axes of

a polarized light coming from a corresponding pixel of the intensity modulating matrix display in a range including 180 degrees and below.

[0009] Other objects, advantages and features of the present invention will become more apparent upon reading of the following non-restrictive description of embodiments thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] In the appended drawings:

[0011] Figure 1 labeled "Prior Art", is a diagram of a conventional stereoscopic display system;

[0012] Figure 2 is a graphic representation of a non-orthogonal polarized stereoscopic display according to an embodiment of a first aspect of the present invention;

[0013] Figure 3 is a diagram of the non-orthogonal polarized stereoscopic display of Figure 2;

[0014] Figure 4 is a diagram of conversion from an orthogonal system into an oblique system;

[0015] Figure 5 is a graphic representation of the non-orthogonal polarized stereoscopic display of Figure 2 in polar coordinates;

[0016] Figure 6 is a diagram of the non-orthogonal polarized

stereoscopic display according to an embodiment of the present invention in the polar coordinates of Figure 5;

[0017] Figure 7 illustrates a system with a haft-length retarder and a quarter-length retarder sheet in the front of the display according to an embodiment of the present invention;

[0018] Figure 8 illustrates effects of the orientation of an optical axis of the retarder sheet of Figure 7;

[0019] Figure 9 illustrates alternatives of the system of Figure 7 and 8;

[0020] Figure 10 illustrates an application of the systems of Figures 7 to 9;

[0021] Figure 11 illustrates an application the systems of Figures 7 to 10 for two players in a game;

[0022] Figure 12 shows a portion of a left-right discrete matrix fine line) and a Modulo-Angular (dotted line) discrete matrix;

[0023] Figures 13 illustrates effects of overdriving an LCD;

[0024] Figure 14 illustrates cross-talk effects between right and left eyes;

[0025] Figures 15 illustrate effects of delaying an angular signal;

[0026] Figures 16 show a corresponding response of the LCD pixel in the case of Figure 15.

[0027] Figures 17 show a resulting pixel intensity at the eye of the viewer, after the left and right polarized filter, in the case of Figure 15;

[0028] Figure 18 is an example of a LCD display using a front diffuser and incident back light, according to an embodiment of the present invention;

[0029] Figure 19 is an example of a LCD display using micro-lens arrays to collimate light within every color sub-pixel, according to an embodiment of the present invention;

[0030] Figures 20 show a lens arrays matching the pixel pitch for a 1280 x 1024 LCD;

[0031] Figure 21 illustrates a lens arrays matching the LCD pixel pitch;

[0032] Figure 22 illustrates a display according to a further embodiment of the present invention;

[0033] Figure 23 illustrates a display using micro-ball array with black mask may be further used to diffuse the light without de-polarizing the light according to a further embodiment of the present invention;

[0034] Figure 24 illustrates a display using a micro-prism according

to a further embodiment of the present invention;

[0035] Figure 25 illustrates a display using micro-lens arrays according to an embodiment of an aspect of the present invention;

[0036] Figure 26 illustrates a display using Holographic Optical Elements sheets according to an embodiment of an aspect of the present invention; and

[0037] Figure 27 illustrates a display using an integrated LCD according to a further embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0038] Generally stated, there is provided a polarized stereoscopic system comprising two polarized filters and generating two polarized images, wherein, contrary to conventional stereoscopic systems (Figure 1), i) the two polarized filters are not necessary located at 90°, ii) the angle of a polarized image is not the same as a corresponding polarized filter i.e. the left filter is not at the left image angle and the right image is not at the same angle than the right filter, and iii) the system of angles is selected is such a way to cancel stereoscopic cross-talk, i.e. leakage from the right image to the left image and vice versa.

[0039] Figures 2 and 3 illustrate a non-orthogonal polarized stereoscopic display system according to an embodiment of the present invention, in a Cartesian system of angles. It comprises passive polarized stereoscopic wearing glasses (see Figure 3) with a left linear polarized filter

L.F. at an angle "A", which is at 90° from a linear polarization angle β of a right image **R.I.**, and a right linear polarized filter **R.F.** at an angle "B", which is at 90° from a linear polarization angle α of a left image **L.I.** It generates two images polarized at an angle ω from each other, where $\omega = \alpha + \beta$.

[0040] In such a system, the intensity of the left image **L.I.** after passing thought the left filter **L.F.** is attenuated by a factor of cosine of the angle between the left filter **L.F.** and the left image **L.I.**, i.e. cos $(A - \alpha)$, while the intensity of the left image **L.I.** after passing thought the right filter **R.F.** is null since the angle $(\alpha + B)$ equals 90° by design and cos (90°) equals zero. Likewise, the intensity of the right image **R.I.** after passing thought the right filter **R.F.** is attenuated by a factor of cosine of the angle between the right filter **R.F.** and the right image **R.I.**, i.e. cos $(B - \beta)$, while the intensity of the right image **R.I.** after passing thought the left filter **L.F.** is null since the angle $(\beta + A)$ equals 90° by design and cos (90°) equals zero.

[0041] As in the present applicant's previous patented polar stereoscopic display system discussed hereinabove, a pixel is subdivided in three sub-pixels controlling the red, green and blue intensities of the pixel respectively, and each corresponding sub-pixels of the left and the right is converted into modular and angular values used to drive the first and the second LCDs of the polar stereoscopic display respectively, following relations (1) and (2) given hereinabove, where **left** is a value of the sub-pixel of the left image corresponding to a same sub-pixel on the right image, and **right** is a value of a sub-pixel of the right image corresponding to a same sub-pixel on the left image.

[0042] Since now the system is non-orthogonal, the **left** and **right**

values are converted from the Cartesian system to the oblique system of angles ω as shown in Figure 4, where **L** refers to the value of the sub-pixel of the left image corresponding to the same sub-pixel on the right image, **R** is the value of the sub-pixel of the right image corresponding to the same sub-pixel on the left image, **x** is the transformed **L** value, **y** is the transformed **R** value, $\omega = \alpha + \beta$ is a polarization angle between the two images, and θ = A - α is a polarization angle between the left filter and the left image.

[0043] The x and y values may be calculated using the following relations:

$$x = L\cos(\omega + \theta) + R\cos(\omega + \theta) \quad (5)$$

$$y = L\sin(\theta) + R\sin(\omega + \theta) \quad (6)$$

Since $90-(\omega + \theta) = \theta$ then

$$x = L\cos(\theta) + R\sin(\theta) \quad (7)$$

$$y = L\sin(\theta) + R\cos(\theta) \quad (8)$$

and relations (1) and (2) become:

$$\text{Modulo}' = \sqrt{\left(x^2 + y^2\right)} \qquad (9)$$

$$\textit{Angular}' = \arctan\left(\frac{y}{x}\right) \qquad (10)$$

[0044] Using relations (7) and (8), relations (9) and (10) yield:

$$\textit{Modulo}' = \sqrt{\left(L^2\cos^2\theta + 2\ L\ R\cos(\omega + \theta) + R^2\cos^2(\omega + \theta)\right)} \quad (11)$$

$$\textit{Angulo}' = \arctan\left(\frac{L\cos\theta + R\cos(\omega+\theta)}{L\sin\theta + R\sin(\omega+\theta)}\right) \quad (12)$$

[0045] Applying the **Modulo'** and **Angular'** transformation yields a polarized angle with a range of ω (from α to β) as shown in the diagram of Figure 5. **L.O.** is a left orientation of a sub-pixel angle value, when the right sub-pixel value is zero or negligible compared to the corresponding left sub-pixel value. It is a minimum generated angular value. **R.O.** is a right orientation of a sub-pixel angle value, when the left sub-pixel value is zero or negligible compared to the corresponding right sub-pixel value. It is a generated angular maximum value.

[0046] The recovery of **L** and **R** from **Modulo'** and **Angular'** with filter at **A** and **B** angles of the non-orthogonal polarized passive glasses recreate the left and the right image for the left and the right eyes as follows:

$$\sqrt{\left(L^2+4LR\cos\theta\sin\theta \;+R^2\right)}\cdot Cos\left(\arctan\left(\frac{L\sin\theta+R\cos\theta}{L\cos\theta+R\sin\theta}\right)+\theta\right) \;=\; left\cdot Cos(2\theta) \qquad (13)$$

$$\sqrt{\left(L^2+4LR\cos\theta\sin\theta \;+R^2\right)}\cdot Sin\left(\arctan\left(\frac{L\sin\theta+R\cos\theta}{L\cos\theta+R\sin\theta}\right)-\theta\right) \;=\; right\cdot Cos(2\theta) \qquad (14)$$

[0047] Figure 6 shows the resulting non-orthogonal polarized polar stereoscopic display system.

[0048] Interestingly, all principles of this non-orthogonal linear polarization system apply to circular polarization stereoscopic systems. A conventional circular polarized stereoscopic display system uses left-handed and right-handed circular polarized filters to separate the left and the right images. The transformation from a linear polarized system to a circular polarized system and vice versa is performed by means of quarter length

retarder films, wherein a fast axis of a retarder film placed at mid angle between the left and the right linear polarized angle transforms the linear polarized light into circular polarization light. In a non-orthogonal circular polarization stereoscopic display system, the linear polarization is thus transformed into an elliptical polarization light by using appropriate elliptical polarized filters instead of the circular polarized filter.

[0049] People in the art will appreciate that the present invention accommodates the low angular range of available commercial LCD panels. Indeed few of these commercial AM-LCD panels turn the light with a range of at least 90°, ranges varying, depending on the technologies such as TN, IPS or MVA, on manufacturers, and on LCD channel amplifier bias, between as low as 65° up to 85°. Moreover, these ranges vary between each primary color: for example, one tested panel may have the red varying from 45° to -25° while the blue varies from 45° to -40°. The non-orthogonal polarized stereoscopic system of the present invention may be adapted for each color, based on the same common polarized glasses.

[0050] People in the art will further appreciate that this aspect of the present invention allows a zero cross talk in a polar stereoscopic display system, as well as a faster switch in a CRT-LC panel stereoscopic display system, and a capacity to overdrive LCD at the extremes ends of angle swing for faster response. Moreover, it allows displaying two independent images polarized at an angle other than 90°.

[0051] By introducing a haft-length retarder and a quarter-length retarder sheet in the front of the display as illustrated in Figure 7, there is provided an elliptical polarized stereoscopic display system. Figure 8 shows how the orientation of the optical axis of the retarder sheet affects the paradigm

of the polarization stereoscopic. Moreover, the half-length retarder sheet may modify the orientation range of the linear polarization portion of the light resulting in even more permutation of linear and circular polarization system.

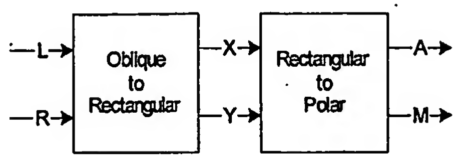
[0052] Therefore, using retarder sheets may increase the number of permutation in the non-orthogonal stereoscopic display system. Some of these permutations allow the selection of stereoscopic glasses where the left and the right elliptical polarized filters have the same amount of light going therethrough when the glasses are placed in front of each other, in such a way that a first person wearing the glasses may look comfortably at a second person wearing similar glasses. Moreover, permutations of filter allow a people wearing them to look comfortably at another LCD monitor.

[0053] People in the art will appreciate that this aspect of the present invention reduces the discomfort typically encountered in others stereoscopic polarized glasses, when looking at regular LCD monitor, wherein one eye sees the image on the monitor but the other eyes see black image, and when looking at another person wearing similar glasses, wherein one eye sees only a first eye of the first person and the other eye sees the second eye of the first person, which results very confusing for the brain.

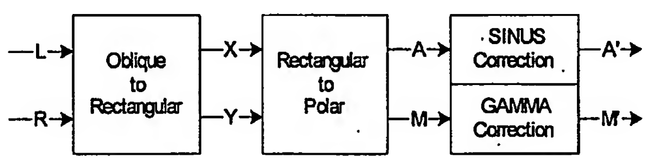
[0054] The present invention provides lock-up tables for rectangular to polar conversion system, for conversion of a live video, described hereinbelow in details, which allows resolving high processing power required to transform left and right images in Modulo and Angular images in real time, and also allows reducing cross-talk by individual combined values (left and right color values).

[0055] As discussed hereinabove, to generate a stereoscopic image,

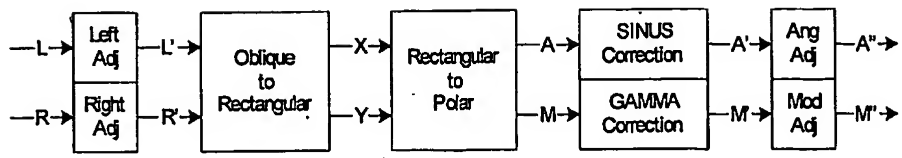
the left and right images are converted to modular and angular values, for every sub-pixel as shown in the following diagram:



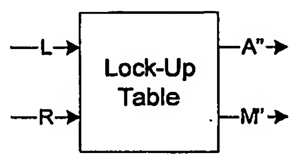
[0056] The pixel light intensity of a regular LCD monitor has a linear response, with or without gamma correction, to a voltage or a value of the signal input. For the modulo signal of a polar system, a Gamma correction is introduced to the Modulo feed in order to obtain a linear LCD pixel M', and a Sinus transformation is used to compensate the LCD light intensity linear response so that the Angular signal generates a linear angular response A', as follows:



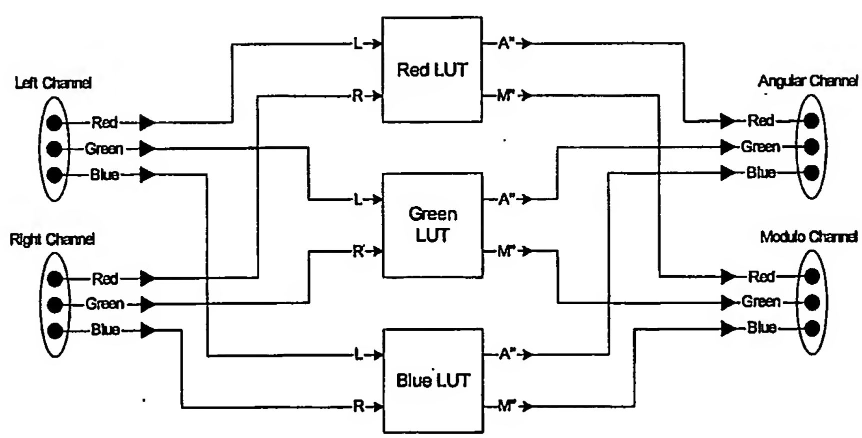
[0057] Adjustment may be further introduced to compensate for a non-perfect response of LCD panel due to polarized filter and electronic, as follows:



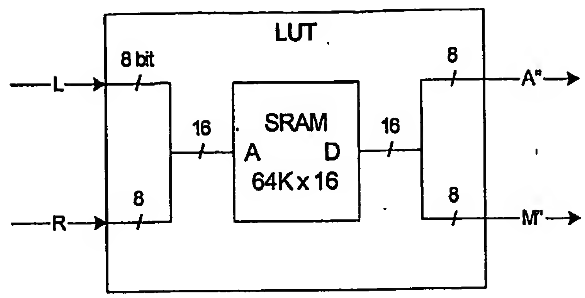
[0058] This processing of the signals may be integrated and stored in a memory used as a Lock-up table, as follows:



[0059] Since each pixel color may have different parameters, a corresponding number of LUT (Lock-Up Tables) are used, one for each color, as shown below:



[0060] The LUT may be implemented in SRAM (static random access memory), as exemplified below:



[0061] People in the art will appreciate that the LUT (Lock-Up Table) is a unique and cost effective tool for achieving a sub-pixel frequency of a 1280 x 1024 at 85 Hz refresh rate, which requires a transformation processing clocked at 480 MHz. Moreover, the LUT makes it easier to introduce any desired adjustment.

[0062] The present invention further allows enhanced contrast and color resolution, whereby the quality of a polar display in normal mode (2D) of may surpass currently available LCD displays by using the front LCD as a second light valve and controlling both LCD's in conjuncture in order to increase a number of available intensity levels. It is also possible to obtain blacker black pixel intensity by blocking more light using both LCD's.

[0063] Simply wearing a different type of polarized glassed (not 3D i.e. both eyes have the same angle) or putting a removable filter sheet on top of the display activates the second LCD as a light valve, instead of as a light twister in stereoscopic mode, which results in more than twice the contrast ratio, 10 bit per color resolution, as illustrated in Figure 9.

[0064] This feature allows private displays, characterized in that, by showing the image on the second LCD while displaying a complete white image on the first LCD, only the person wearing the polarized glasses (same as

for enhanced contrast) is able to see the screen, while other people only see a white screen (Figure 10).

[0065] Furthermore, instead of showing a white image on the first LCD of the private display, it is possible to show a fake image that people not wearing the polarized glasses see, giving them the illusion of a normal display, while the person wearing the glasses actually looks at a different image. The private image to be shown on the second LCD is processed to remove the first image for the person wearing the polarized glasses. The image on the first LCD is selected or transformed to have enough brightness at every pixel so that each pixel of the second LCD has sufficient light to display the private image.

[0066] In the case of two players in a game or example, each player may thus see different images on the same display. The first player wears glasses with both eyes at a first polarized orientation and the second player wear glasses at a second polarized orientation. The two orientations may be orthogonal or non-orthogonal as discussed earlier hereinabove (Figure 11).

[0067] Therefore, the same display may switch, at the push of a button for example, between a normal 2D screen, a stereoscopic screen (by wearing passive 3D glasses), an enhanced 2D screen (by adding a film on the display surface), a security display screen (where only the person wearing special glasses see the image), and a two players- two displays- single screen-full screens display screen.

[0068] Another problem may be solved in the present invention, such as cross talk, which may be reduced by using 2D matrix average of alternative display field. Indeed, digitalization (for converting the signal to

discrete levels, for example 256 levels) of the modular and angular signal leads to quantization errors, which in turn may cause cross talk. Even if the Cartesian to polar conversion does not generate errors, errors may still be caused by rounding of the modular and angular values, which in turn may creates a difference between the original left and right values and the display intensities.

[0069] Figure 12 shows a portion of a left-right discrete matrix fine line) and a Modulo-Angular (dotted line) discrete matrix. The closest modular and angular discrete values are used to represent the left and right values but, as shown on the diagram, for some values combinations, the error may be quite large and may result in quantization errors and cross-talk. To minimize such error, it is contemplated to toggle at every video frame, or at a different rate but fast enough to prevent any flicker perceived by the viewer, between two Modulo-Angular discrete values in order to so obtain an average, which is closer to the left-right values (full line).

[0070] Cross talk may be further reduced for fast moving images using LCD overdrive technique and using pre-angular adjustment, as will now be described.

[0071] Overdriving a signal to a LCD during a short period of time, such as during one video frame for example, accelerates a change of orientation of the LC crystals and yields a final value faster (Figure 13). This system may work as well with high to low pixel value changes. However overdriving may be limited at the extreme value of pixel intensity, i.e. zero and 255 for an 8-bit/color pixel, due to the lack of room to drive a higher or lower value. The present non-orthogonal stereoscopic display allows adding room for overdriving by reducing the angular range, thereby allowing an angular LCD of

the display response faster at all values, which results in cross-talk reduction. Using a LCD overdrive as described hereinabove allows reducing crosstalk caused by the intermediary angle when the angle changes from one frame to the following frame, and reducing fast moving image smearing.

[0072] Now, turning to cross-talk reduction for fast moving images by using pre-angular adjustment, it is noted that the intensity change in a first eye may cause spurious light in the second eye, for example when a pixel of the right eye image changes from bright to dark while the corresponding pixel of the left eye image is dark (Figure 14).

[0073] The top diagram of Figure 15 shows a normal system and the bottom one shows a system where the angular signal has been delayed, by one the time of one video frame for example. The corresponding response of the LCD pixel is shown in Figures 16. The resulting pixel intensity at the eye of the viewer, after the left and right polarized filter is shown in Figures 17.

[0074] It may be seen that the slow response of the LCD creates a temporal gap during which the light passes through the left eye filter, which does not occur when the angular signal is delayed. Similarly, it may be demonstrated that a light bump appearing when the intensity of a pixel of one image goes from dark to bright while the other image is dark may be prevented by delaying the Modulo signal. A basic rule to apply delay may thus be stated as follows:

- when a sub-pixel, the left or the right, goes from dark to bright while the other corresponding pixel, the right or the left, is dark, then delay the Modulo signal relative to the angular signal; and

- when a sub-pixel, the left or the right, goes from bright to dark while the other corresponding pixel, the right or the left, is dark, then delay the Angular signal relative to the Modulo signal.

[0075] The overdrive technique may also be used to advance a signal instead of delaying it. The overdrive and delay techniques may be used together.

[0076] Another problem is dealt with by the present invention. It is well known that superposition of two-pattern structures, such as two LCD cells for example, causes a Moiré pattern due to the interference of the two structures. With the LCD of the present invention, only one incident light ray goes through a same pixel and a same color filter, while the other two are blocked by a color filter. The corresponding pixel of the two LCD panels work together so that at a given angle, there is a mismatch of the modulo pixel and the angular pixel, which results in parallax cross talk between the left and right images and degradation of the image resolution. The interference between the two LCD panel pixel structures causes low display brightness, which adds to the low brightness inherent to stereoscopic systems since the light is split between the two eyes.

[0077] The present invention allows solving the interference problem of stacked LCD panels and improving contrast at wide view angle, by allowing the collimation of light using one or more Micro-Lens Arrays layer placed before, in-between and/or after, the two LCD panels. The examples illustrated in Figures 18 and 19 allow very large viewing angle since the light goes thought the pixels at a fixed angle, in contrast with standard LCD's in which the contrast reduces and the color shifts with the angle of view.

[0078] Figure 18 illustrates an embodiment using a front diffuser and incident back light. Figure 19 illustrates an embodiment with micro-lens arrays to collimate light within every color sub-pixel.

[0079] The pitch of the micro-lens arrays matches the LCD pixel pitch or sub-pixel pitch. Figures 20 show a lens arrays matching the pixel pitch for a 1280 x 1024 LCD. The light radiated from the backlight is focused through the pixel aperture of the first LCD and through the corresponding pixel aperture of the second LCD. Then the light coming out of the aperture of the second LCD may be diffused either by micro-lens or by a light diffuser layer or both. The micro-lens arrays may also be Gradians Index (GRIN) lenses type.

[0080] For the micro-lens base examples below, the lens arrays matches the LCD pixel pitch as shown in Figure 21.

[0081] Alternatively, the color filter of the LCD panel may be used to create a parallel barrier and derivate the red and the blue light rays to the left adjacent and right adjacent pixels column of the angular LCD respectively. The electronics driving the LCD may be made to compensate for the shift by advancing the red and retarding the green channel by one pixel or vice versa if the LCD panel color matrix is BGR instead of RGB (Figure 22). Furthermore, the fixed angle of light inside the display of the present invention allows the use of cholesteric color and polarized filters, which allows brightness gain of up to 600%, thereby compensating for the low brightness discussed hereinabove.

[0082] Another method to increase the brightness of the display of the present invention makes use of a grating optical element for separating the color instead of filtering it, which, in combination with micro lens arrays, may yield an increase in brightness by 300%. A micro-ball array with black mask

may be further used to diffuse the light without de-polarizing the light (as with the other type of diffuser), as illustrated in Figure 23.

[0083] Furthermore, a micro-prism may be added to deviate the red and blue light ray so they are perpendicular to plane as the green, as shown in Figure 24.

[0084] Such making use of micro-lens arrays or GRINS lens arrays resolves the problem associated with the superposition of two pattern structures, such as the LCD cells, discussed hereinabove in relation to Figure 7, by preventing the light ray at certain angle to go through the modulo LCD pixel adjacent the corresponding angular LCD pixel (at the same coordinate), which otherwise would result in parallax cross-talk between left and right images and a degradation of the image resolution. Therefore, brightness increased by allowing more light going through pixel aperture, and a very large viewing angle is obtained because the light goes thought pixel at a fixed angle.

[0085] Mini-lens arrays or GRINS lens arrays may further be used to perform the first and second LCD images replication (Figure 25). One or more mini-Lens Arrays layers are placed in-between the two LCD of the stereoscopic display. These mini-lens arrays are selected to form a non-inverted 1:1 image projection, so that the light going through a sub-pixel of the first LCD goes through the corresponding sub-pixel of the second LCD. The pitch of the mini-lens arrays does not have to match the LCD pixel pitch. The mini-lens arrays may also be Gradians Index (GRIN) lenses type.

[0086] A display using Holographic Optical Elements sheets to redirect the light to the corresponding pixels of the first LCD and the second LCD is shown in Figure 26.

[0087] Replication of the first and second LCD further resolves the problem associated with the superposition of two-pattern structure discussed above.

[0088] The LCDs of the present invention may be integrated as illustrated in Figure 27, wherein the two LCD panels are integrated into one LCD panel. Since then the modulo and the angular LCD structures are close together, the light from the backlight is directed through both corresponding pixels even at wide angles. A typical LCD panel is made of two glass substrates of a thickness typically around .7mm, a first glass substrate comprising the active part of the LCD and a glass substrate comprising the black matrix, the color filter and in certain case an IPO conductive layer acting as the anode or cathode. The liquid crystal is located in between these two substrates. For an integrated LCD according to the present invention, two active .7mm substrates may be used, the first one controlled by the modular signal and the second one controlled by the angular signal. A very thin sheet, less than .2mm, and made in glass or other material, comprising an IPO conductive layer and the color filter is placed between the two active glass substrates, and the middle thin sheet is the liquid crystal. The two active substrates and the color filter are to be aligned. The second active substrate may have a black matrix layer. Again, such a structure resolves the problem associated with the superposition of two-pattern structure discussed above.